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ABSTRACT

One of a series of general interest publications on science issues, this booklet describes the uses of tree rings in historical and biological recordkeeping. Separate sections cover the following topics: dating of tree rings, dating with tree rings, tree ring formation, tree ring identification, sample collections, tree ring cross dating, tree ring patterns, and present and future uses of tree rings. Numerous photographs and diagrams illustrate tree ring classifications and uses. (LP)

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Tree Rings:
Timekeepers of the Past

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Trees Are Historians

Everyone delights in the beauty and the vitality of living trees. They provide us with an endless source of pleasure, for even though most of us are exposed to trees every day, we never tire of them. Indeed each year more and more of us turn to the forests and the woodlands for vacations and for retirement. Perhaps trees fascinate us because they are truly the "giants" of the plant world; we are awed by their size and their silent strength, and this in turn may cause us to wonder about the life forces contained within the trees' structure.

Botanists and hydrologists have long sought to unravel the secrets of these life forces from Nature's "giants"—to determine what hydrologic and environmental information is revealed by their growth records. They have discovered that trees are Nature's timekeepers, her historians. Trees tell a fascinating story but, to understand it, we must look inside the tree. And herein lies our story.

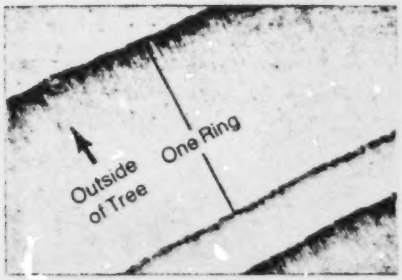
If you look at the top of a tree stump, you will see that it is composed of a series of concentric rings—*tree rings*—that become larger and larger in diameter outward from the center of the stump. Tree rings possess highly individualized characteristics that reveal many facts about past water and climatic conditions. For example, suppose you notice that several of the stump's tree rings seem unusually narrow. You have just unraveled part of the story of this Nature's timekeeper—these narrow rings may be climatic records of extreme drought years. Because a single tree ring, a growth ring, is usually formed each year, the age of the tree when it was cut can be determined by counting the rings. If the year of cutting is known, the year during which each ring was formed can be determined by counting backwards from the outside ring. This process is called "dating."

What Are Tree Rings?

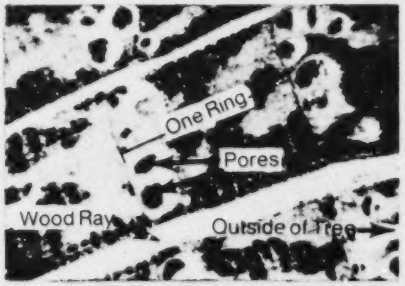
To grow, trees must increase the size of their *xylem* (woody portion exclusive of bark) by adding new tissue between the existing xylem and the bark. Such new growth usually occurs according to a seasonal pattern. Trees in temperate regions typically experience an annual cycle—a summer growth period that begins with the opening of leaf buds in spring and a winter dormant period that begins with the dropping of leaves in autumn.

Growth depends upon the abundance of soil moisture in this annual cycle. Moisture normally reaches its peak of availability in early spring and its low in late summer. In response to this moisture cycle, the growing tree forms two types of cells: large thin-walled cells in the early part of the growth season when soil moisture is abundant, and small thick-walled cells during the latter part of the growth season when soil moisture is less available.

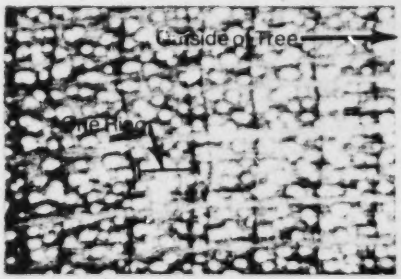
Tree-ring boundaries are distinguished as an abrupt change of appearance between the small thick-walled cells produced at the end of a growth season and the large thin-walled cells produced at the beginning of the next growth season. The wood between these two consecutive boundaries is formed during one growth season and thus is technically referred to as an *annual increment of growth* or, more popularly, as *a growth ring* or *tree ring*. The three basic categories of wood types show their highly individualized ring characteristcs.



NONPOROUS WOOD— Ring boundaries of most nonporous wood (such as most evergreens) are the breaks between the band of darker colored cells (the small thick-walled cells formed at the end of a growth season) and the much lighter colored wood just outside the dark band.



RING POROUS WOOD — The ring boundary of ring porous woods (such as the oaks) is the break between the small thick-walled cells formed at the end of a growth season and the very large open vessels or pores formed at the beginning of the next season of growth.



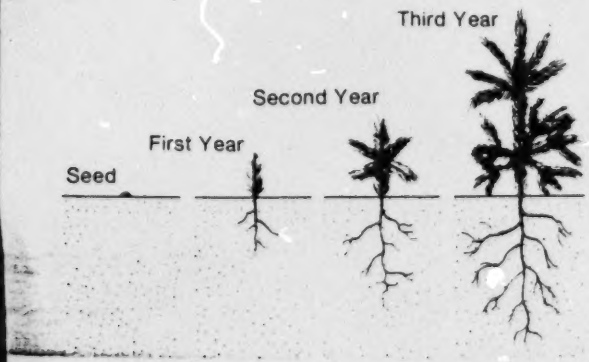
DIFFUSE POROUS WOOD — Although often difficult to distinguish with the naked eye, the ring boundary of diffuse porous wood (including maples, yellow poplars, and sycamores) is the area between the fine light-colored lines formed at the end of the growth season by very small thick-walled cells.

Tree Rings: Growth Layers

Looking down at a stump top, it may be difficult to visualize how tree rings go together to make a tree. Perhaps this is because a tree is a three-dimensional object and a stump top displays only two dimensions. The idea of three-dimensional growth can be clarified, however, by disregarding for the moment the leaves, branches, roots, and bark, and considering only the wood portion of the tree trunk.

At the end of its first summer, after germination from a seed, a tree seedling is composed of one annual growth increment or growth layer. This somewhat cone-shaped increment, a fraction of a centimeter in diameter and only a few centimeters high, will not grow or change dimensions after the year in which it was formed, but will remain the same size and in the same position as long as the tree exists.

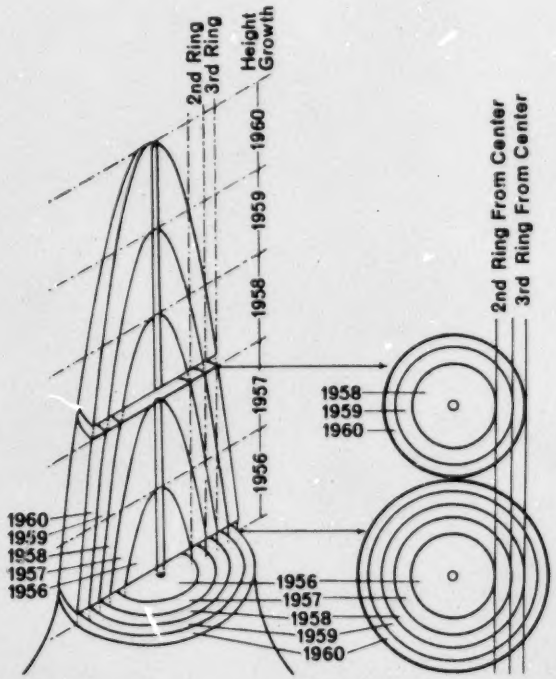
During the second year, another annual growth increment is formed around and above the first year's increment. At the end of the third year, an increment has been formed around that of the second year, and similar cones of growth are formed in each succeeding year. The growth increment of each year thus increases the diameter and height of the tree trunk;



Each year a tree grows it adds another growth ring.

but once each increment has been formed, it remains unchanged in size or position during the life of the tree.

Tree rings form a part of Nature's permanent historical record of environmental conditions. For example, consider a non-typical year such as a year of extreme drought. A tree will undergo little new growth during such a year. As a result, growth may not extent to the base of the tree, and a tree ring may not be formed in the basal section of the trunk. Whether or not a ring is missing can be determined by comparing a section of basal rings with a section



The illustration of a tree trunk represents a hypothetical situation that would result from growth under average environmental conditions (no floods, no droughts, no extreme temperatures). In general, growth begins at the top of the tree and progresses toward the base. Although the width of each ring (the "ring size") decreases from the center, the total cross-sectional area remains the same for each year.

of rings containing all growth rings but taken higher in the trunk. The missing rings are visual records of years of extreme environmental conditions—in this case, of years of drought.

Tree rings also are a record of vegetative history in a particular area. Trees that have grown up in an environment free of competition for sunlight and moisture exhibit a pattern of large open ring growth, particularly within the early growth years. In contrast, trees that have developed in a highly competitive environment will reveal an early growth pattern of narrow, closely compacted rings. Depending on the degree of competition, tree-ring patterns will change. Tree rings provide a continuous record of vegetative change and environmental effects.

Even though these two sections contain the same number of tree rings, they show the effect of the environment on ring growth. Section A is from the Colorado blue spruce that was transplanted to the White House lawn and used as the National Christmas Tree, 1975-76, and shows the large rings formed in trees growing in lawns and other open areas. Section B is from a Virginia pine that grew at Cedarville State Park in Maryland and shows the narrow growth rings more typical of trees with small crowns, such as understory trees in eastern forests.

Collecting Tree-Ring Samples

Tree stumps, the ends of logs, and the tops of posts provide the best opportunities to examine tree trunks in cross section. An interested observer can usually find some good tree rings to examine in his immediate neighborhood and in nearby wooded areas.

Botanists and foresters, who need to examine many tree-ring samples and cannot be limited to looking at rings from trees that have been cut down, have devised a tree-boring method to collect tree-ring samples from living trees without harming the trees. This method uses a hollow metal bit, called an *increment borer*, which is twisted into a standing tree to remove a pencil-sized sample or *core*. This sample provides valuable tree-ring data that can be readily stored for later laboratory studies.

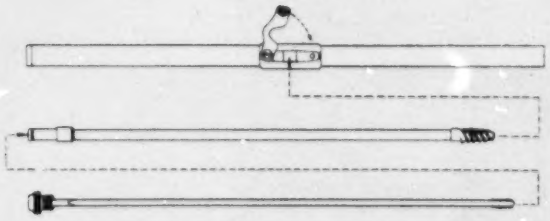


Diagram of an increment borer—a tool used in obtaining core samples from live trees.

Tree Rings: Historical Records

Counting the rings of a single cross section, such as a stump top, reveals the number of years the tree grew after it reached that height. By counting backwards from the year of the outside ring (year of last growth season before the tree was cut), each ring may be labeled with the year during which it was formed. If any rings were missing, then the dating is inaccurate. If none of the rings were very small, however, it is unlikely that any will be missing.

Knowledge of the ages of selected trees in an area provides a time reference for climatic/environmental conditions or events of historical significance. For example, tree ages can indicate:

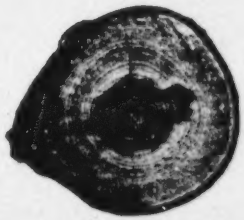
(1) the minimum number of years since a land surface first became suitable for germination and growth of tree seedlings;
(2) the minimum length of time since farmland was abandoned or no longer cultivated; or
(3) the minimum number of years since new land surfaces were created, such as by land fills, road cuts, floods, or glaciers.

The specific year during which a tree was damaged can also be determined if the tree rings can be dated. Thus it is possible to date the event or condition that damaged the tree. If a patch of bark has been removed from the tree, which kills the delicate growth tissue beneath, the date of such damage can be determined by counting the number of rings in an adjacent undamaged area after the damage occurred. This method has been successfully used to date and identify such events as forest fires, ice jams on rivers, and the blazing (marking) of boundary trees.

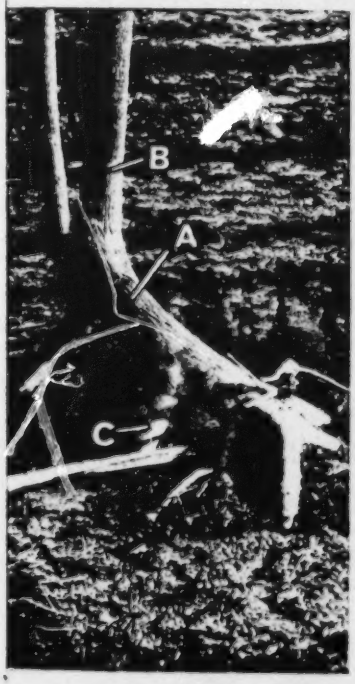
Tree-ring counts have also been used to date events such as floods, landslides, and hurricanes, that have partially tipped trees. Terminal shoots of trees tend to grow upward. If a tree is tipped over, new shoots will emerge and grow vertically at an angle to the axis of the bent-over trunk. The event that tipped the tree can be dated by counting the number of rings in the new shoots that have grown vertically from the tipped trunk.

Tree-Ring Cross Dating

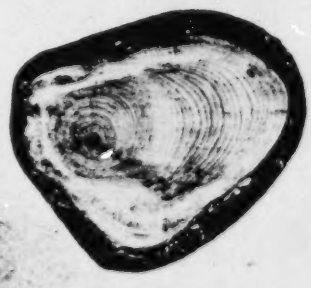
Cross dating is a method of dating wood (including trees, posts, and structural



Date of damage to tree trunk can be determined by counting number of rings formed after (to the outside of) the damaged ring.



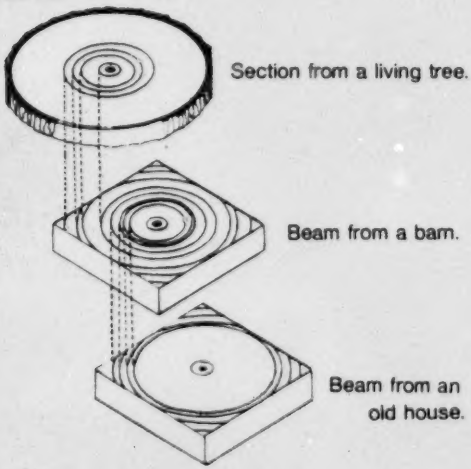
Ash tree, on flood plain, that was knocked over by one flood, partly buried by another, and exposed by third. (A) Original trunk tipped over by flood. (B) Vertical sprout that grew after tree was tipped over by flood. (C) Root that grew from tipped trunk after the second flood and then was exposed by a third flood.



Concentric rings near the center were formed when trunk was in an upright position. The outer eccentric rings were formed after the trunk was tipped.

beams) by comparing the ring patterns in the older wood with the patterns in more recent wood. Such dating is possible because of the variation in ring size. Examination of a number of wood samples from a given area reveals that variation in ring sizes appears to follow a pattern.

If the same ring pattern can be identified in two pieces of wood, one of which has been dated, the second piece can be dated from the first by matching the ring pattern common to both pieces. This method is called *cross dating*. Scientists at the University of Arizona Laboratory of Tree-Ring Research have used this method to establish continuous ring records of more than 6,000 years. With such records, the scientists have been able to determine when trees used as structural beams in ancient Indian cliff dwellings were cut. Elsewhere, cross dating has also enabled historians to date locally obtained wood more than 100 years old, such as wood used for structural beams in buildings constructed by early settlers.



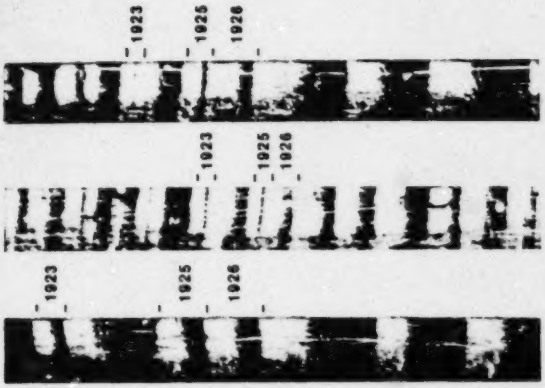
Ring patterns of undated wood samples can be matched or cross dated for age with other samples that have been dated by identifying the ring pattern common to all samples.

Cross dating can also be a useful tool in working with short records from more recent samples of wood. For example, cross dating can be used to determine when a tree was killed by recent but unrecorded floods, fires, or other events. In the case of floods, the position of the dead tree on the stream bank also gives a minimum height for the flood.

Tree-Ring Patterns

Examination of a stump top may reveal an occasional very small ring that, upon dating, is found to correspond to a known year of extreme drought. Further, an occasional very large ring may correspond to a known year of excessive rainfall. Between these two extremes, rings may vary considerably without correlating directly with any extreme environmental conditions. Obviously, many combinations of environmental factors can result in a tree ring of the same size. The more complex the environment, the more difficult it is to sort out the particular combination of factors that have produced a certain ring size for a given year.

Cross dating depends on this pattern of variation in ring size. Within a given area, the ring patterns of trees of one kind may be quite similar. In addition, the patterns found in different kinds of trees in the area may resemble each other. The similarity must be caused by something common to all the trees—environment. Because each tree grows in a somewhat different microenvironment, however, parts of its ring pattern are also somewhat different from those of other areas. Therefore, similarities in ring patterns can be expected among trees in an area resulting from those aspects of the areal environment common to all trees. In addition, the more closely trees from a given area cross date with each other, the more closely the ring patterns will be expected to match regional climate patterns. Much research, particularly in the Great Dismal Swamp, Va., has gone



Adverse environmental conditions during 1923, 1925, and 1926 slowed growth and produced narrow tree rings in three different loblolly pine trees growing in the Great Dismal Swamp, Virginia. Note that the narrow ring pattern is reflected not only in total ring width of earlywood (light portion of ring) but also in latewood (dark portion of ring).

into determining what kind of tree and what habitat combine to result in tree-ring patterns that more closely reflect regional environmental conditions rather than local microenvironmental deviations.

Present and Future Uses of Tree-Ring Studies

Dating *of* tree rings and dating *with* tree rings have been perfected to the point that tree rings may be used to date numerous events and conditions. The University of Arizona Laboratory of Tree-Ring Research has made considerable progress in calibrating tree rings from the West and Southwest with climatic conditions. These calibrations have been used successfully to reconstruct climatic conditions of the past 400 years throughout North America. It will be possible to greatly refine these reconstructions as tree-ring collections from the East become available and can be incorporated into calibrations.

At present, the Water Resources Division of the U.S. Geological Survey maintains a Tree-Ring Laboratory at the National Center

A television system used for detailed scanning and measurement of wood samples at the Tree-Ring Laboratory in Reston, Virgina.

in Reston, Va. (near Washington, D.C.). The laboratory conducts research relating tree growth with hydrology. Studies are being conducted to help hydrologists use tree rings to estimate hydrologic conditions in areas where no other records exist and for periods before records were collected. Research has demonstrated that tree-ring records in the humid Eastern United States can be successfully cross dated. This has led to current research in calibrating tree-ring records with hydrologic records that will enable estimation of yearly variation in streamflow of small streams and water-level variation in forested wetlands.

Tree-ring studies have revealed many ways in which changes in various climatic/environmental factors affect growth throughout a tree and have demonstrated that much information about past environmental conditions may be reconstructed from tree rings. Thus used, trees serve as natural recorders of the environments in which they live. Tree rings are already proving to be excellent historians, but much work remains to be done before we will use fully and see clearly through these windows to the past.

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